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NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE

AND THE

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING

RALEIGH AND WEST RALEIGH

DIVISION OF ANIMAL INDUSTRY

# COMPOSITE VERSUS ONE-DAY SAMPLING OF MILK FOR THE BABCOCK TEST

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# COMPOSITE VERSUS ONE-DAY SAMPLING OF MILK FOR THE BABCOCK TEST

By W. H. EATON, Dairy Experimentalist.

The milk record sheet and Babcock tester have long been recognized as absolute necessities on every practical dairy farm where guesswork has been eliminated and where the dairy is being conducted strictly on a business basis. One day, each month, is usually set apart as the sampling day, and samples of milk are taken from each milking from every cow in the herd. Butter-fat tests are made from these mixed samples from the two milkings and the per cent of butter-fat, as determined by this one-day test, is used in determining the production for the month in which the test was made. The total pounds of butter-fat produced during the month is calculated by multiplying the pounds of milk produced during the month by the butter-fat test for that month.

In the minds of many dairy farmers the question frequently arises as to the accuracy of the fat production when estimated from the milkings of one day. Is this system of sampling accurate enough for average farm purposes, and is it a fair test from the standpoint of the cow? For the purpose of answering these questions intelligently and to determine the accuracy in estimating the butter-fat production of cows from milk samples taken from one day's milking during each month, a test was made with twelve cows covering a period of ninety days.

## PLAN OF EXPERIMENT

Twelve cows from the herd of the Branch Experiment Station, Willard, N. C., were selected for this experiment, and at the end of each month of the experiment the butter-fat production was estimated for each cow by two methods of sampling, namely: the one-day-per-month and composite methods. Six cows were on test during the months of April, May, and June, and were replaced by six additional cows during the months of July, August, and September. Cows were selected in various stages of lactation in order that the results might compare with average herd conditions in North Carolina. Accurate records were kept showing the daily production of milk in pounds.

## METHOD OF TAKING SAMPLES

In estimating the butter-fat production by the composite method of sampling, the following plan was carried out: A sample of milk was

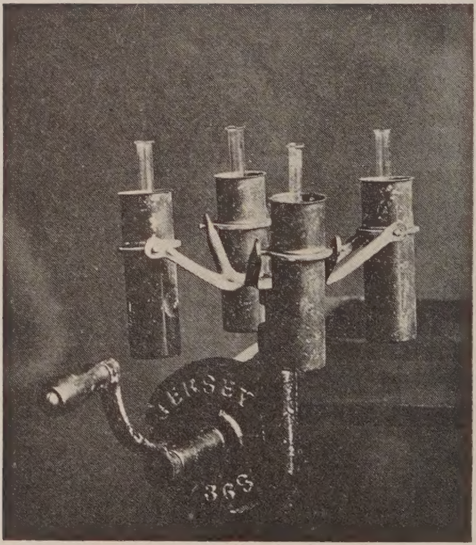


FIG. 1.—BABCOCK MILK TESTER.

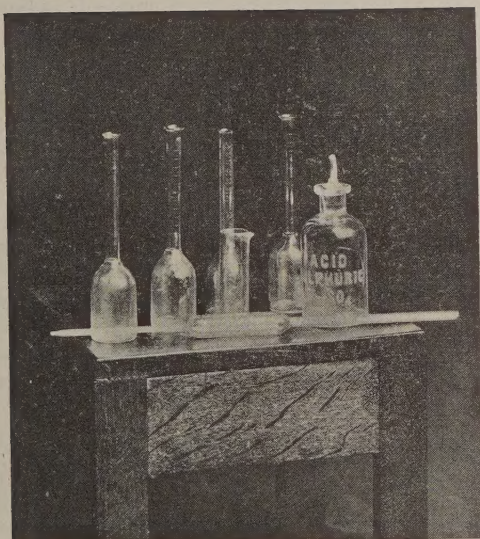


Fig. 2.—Equipment for Making Babcock Milk Test.

taken from *each* milking of the twelve cows on test and was kept in a tightly stoppered bottle bearing the name and number of the cow being tested. A butter-fat test then was made once each week from this composite bottle containing the small samples taken throughout the week. At the end of each week, during the test, the butter-fat production was estimated *by multiplying the pounds of milk produced by the butter-fat test.* The butter-fat production for the month as determined by the composite method of sampling was obtained by taking the total of the weekly production during the month.

In estimating the butter-fat production by the one-day-per-month method of sampling, the work was carried out as it is done on the average dairy farm in North Carolina. A sample was taken from the two milkings during one day of each month of the experiment. The samples for this one-day test were taken in all cases as near the middle of the month as possible. The monthly butter-fat production for the cows was estimated by multiplying the pounds of milk by the fat test for the month as determined from the one day's samples.

## RESULTS OBTAINED

Table I—Butter-fat Production

| Cow No. | Month | Pounds Milk | Average Per Cent Test | | Total Pounds Fat | |
|---|---|---|---|---|---|---|
| | | | Composite | One-Day | Composite | One-Day |
| 1 | April | 627.4 | 4.16 | 4.20 | 26.14 | 26.35 |
| 2 | April | 841.3 | 4.33 | 4.20 | 36.51 | 35.33 |
| 3 | April | 626.4 | 4.24 | 6.00 | 26.57 | 37.58 |
| 4 | April | 604.5 | 4.07 | 5.60 | 24.65 | 33.85 |
| 5 | April | 206.6 | 6.19 | 6.40 | 12.79 | 13.22 |
| 6 | April | 807.8 | 4.34 | 4.60 | 35.10 | 37.15 |
| Total average | | 3714.0 | 4.35 | 4.94 | 161.76 | 183.48 |

Monthly records of the butter-fat production during the experiment were kept in the form as shown in the above table. Under the column headed average per cent test will be noted the average monthly tests as determined by the tests made from the samples taken by the two different methods. The total pounds of fat produced per cow as estimated by the two methods of testing will be noted under the total fat column.

TABLE II—BUTTER-FAT PRODUCTION OF TWELVE COWS

Estimated by Composite and One-Day Babcock Testing

| Cow No. | Period | Pounds Milk | Butter-fat, Per Cent Test | | Pounds Fat Produced | |
|---|---|---|---|---|---|---|
| | | | Composite | One-Day | Composite | One-Day |
| 1 | 90 days | 1667.9 | 4.21 | 4.54 | 70.31 | 76.64 |
| 2 | 90 days | 2199.8 | 4.39 | 4.26 | 96.71 | 93.90 |
| 3 | 90 days | 1645.4 | 4.35 | 5.11 | 71.48 | 84.07 |
| 4 | 90 days | 1694.8 | 4.37 | 5.44 | 74.08 | 92.30 |
| 5 | 90 days | 1387.7 | 5.13 | 6.43 | 71.23 | 89.35 |
| 6 | 90 days | 2045.5 | 4.27 | 4.45 | 87.39 | 91.21 |
| 7 | 90 days | 820.5 | 4.95 | 5.19 | 40.68 | 42.65 |
| 8 | 90 days | 625.8 | 4.13 | 4.82 | 25.89 | 30.17 |
| 9 | 90 days | 858.6 | 5.50 | 5.73 | 48.06 | 49.27 |
| 10 | 90 days | 937.8 | 4.73 | 4.96 | 44.45 | 46.53 |
| 11 | 90 days | 942.6 | 4.96 | 4.96 | 46.81 | 46.84 |
| 12 | 90 days | 753.8 | 5.30 | 5.76 | 40.42 | 43.43 |
| Total average | | 15580.2 | 4.60 | 5.04 | 717.51 | 786.36 |

The above table represents a summary sheet made up from the six monthly records of which Table I is a specimen. The butter-fat tests shown in Table II are the average tests for the three months period of the experiment. The estimated butter-fat production is shown as calculated by the two experimental methods. Under the total average column will be found the total herd production and also the average herd tests.

TABLE III—SUMMARY TABLE

Butter-fat Production from a Herd of Six Cows. Estimated by Composite and One-Day-Per-Month Tests

| Month | Pounds Milk | Average Per Cent Test | | Total Pounds Fat | |
|---|---|---|---|---|---|
| | | Composite | One-Day | Composite | One-Day |
| April | 3714.0 | 4.35 | 4.94 | 161.76 | 183.48 |
| May | 4321.5 | 4.30 | 4.85 | 186.15 | 209.23 |
| June | 2605.6 | 4.73 | 5.17 | 123.29 | 134.76 |
| July | 2177.4 | 4.48 | 5.62 | 97.72 | 122.31 |
| August | 1495.9 | 5.24 | 4.81 | 78.43 | 72.02 |
| September | 1265.8 | 5.54 | 5.10 | 70.16 | 64.56 |
| Total average | 15580.2 | 4.60 | 5.04 | 717.51 | 786.36 |

TABLE IV—DIFFERENCE IN ESTIMATED BUTTER-FAT PRODUCTION

| No. Cows | Days on Test | Kind of Test | Pounds Milk | Average Fat, Per Cent | Pounds Estimated Fat |
|---|---|---|---|---|---|
| 12 | 90 | One-Day | 15580.2 | 5.04 | 786.36 |
| 12 | 90 | Composite | 15580.2 | 4.60 | 717.51 |

| | |
|---|---|
| Difference in favor of One-Day Test | 68.85 pounds fat |
| Monthly average difference per cow | 1.91 pounds fat |
| Monthly average difference per cent test | 0.441 per cent |

## SUMMARY

It is an established fact that the butter-fat content of milk varies constantly, and at times widely, from day to day and even between milkings on the same day. It is impossible to give the exact range of this variation in fat.

The chief causes usually given for these variations are: change in milkers, influence of weather conditions, undue excitement of any kind, and the general health of the animal.

From the result of the experiment with twelve different cows, covering a test period of three months, the butter-fat production as estimated by the one-day-per-month method of testing was 786.36 pounds. The production from the same cows during this period as determined by a composite test taken from each milking was 717.51 pounds.

For the herd of twelve cows during the three months experiment the one-day-per-month test showed an increase in fat production of 68.85 pounds over the production as determined by the composite test.

The fat production as estimated by the one-day-per-month test was 1.91 pounds higher per cow per month than the production estimated by the composite test.

For practical purposes the one-day sampling of milk for the Babcock test gives reasonably accurate results.

For purposes of accuracy in the determination of butter-fat production composite samples from the complete milkings of two or more days should be taken each month.

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# REPAIR OF BONE IN DOMESTIC FOWL

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†On leave.

# REPAIR OF BONE IN THE DOMESTIC FOWL

B. F. Kaupp, Poultry Investigator and Pathologist, Animal Industry Division

In presenting this material the work is divided into three groups, as follows:

1. The structure and development of the bones of fowls.
2. The kinds of fractures and the reparative processes.
3. Means of controlling the bird and care of the fracture.

## I. The Structure of Bone

The bones of the domestic fowl may be divided into four classes, as follows: long, short, flat, and irregular.

Long bones are found in the limbs, where they form a system of levers to sustain the weight of the body and confer the power of locomotion upon it. The femur, tibia, and humerus are examples of this class. The shaft of the long bone is contracted and narrowed to afford greater space for the bellies of the muscles. The extremities generally are somewhat expanded for greater convenience of motor connection, for the purpose of articulation, and for affording a bony surface for muscular attachment. Some long bones are slightly curved, thus affording greater strength to them.

Short bones may be found where a part of the skeleton is intended for strength, with its motion slight and limited, and where it is divided into a number of small pieces, united by ligaments. Here the separate bones are short and compressed. The bones of the toe are examples of short bones.

The patella and the two carpal bones are irregular.

Flat bones may be found where the principal requirement is extensive protection or large bony surface for muscular attachment, osseous structures expanded into flat bony plates, are found, as in the case of the skull and pelvis. In the cranial bones, also, there are layers of compact tissue known as tables. The outer table is thick and tough; the inner table thinner, denser, and more brittle, and, therefore, termed the vitreous table, while the intervening cancellated tissue, which is permeated by air spaces, is called diploe.

Many of the bones of the fowl, as the head, vertebra, and humerus, contain air cavities partitioned off by fine bony structures and into which cavities the air sacs send extensions. The respiratory apparatus of the fowl consists of two lungs, which occupy the upper thoracic region, pushing out between the ribs and composed of a series of tubes. Some of the bronchi or air tubules communicate with air sacs or blad-

der-like structures located at the anterior thoracic region, others at the diaphragmatic and abdominal regions, and these send extensions into the bones.

Studying more minutely the structure of bone, it is found that it nearly always develops from a connective tissue foundation. The inorganic substance of the bone is compressed in or between the fibers of connective tissue, while the cells of the latter are transformed into bone cells. Between the fibers are uncalcified bone cells, each of which rests in a cavity of the matrix called a lacuna.

Primarily, bone consists of a single thin lamella, its later complicated structure being produced by the formation of new lamellæ in apposition to the first. During its development the bone becomes vascularized and the vessels are inclosed in especially formed canals, known as haversian canals.[1]

The bone cells have processes that anastamose with the processes of other cells. They lie in special canals known as canaliculi.

### *Appearance of Transverse Section of Bone*

The appearance presented by a transverse section of a long bone is as follows: In the center there is a large cavity which in fetal and early chickhood nearly always contains marrow, but later such bones as the humerus contain air spaces. The periphery of the bone is covered with a dense connective tissue membrane, the periosteum. In the young this membrane may be divided into three layers, the outer consisting mainly of rather coarse white fibrous tissue; the middle, fibro-elastic tissue, and the inner, the osteogenic layer. The inner membranous layer is vascular and rich in cellular elements. In the adult bird the osteogenic layer has practically disappeared, leaving here and there a few of its cells, while the fibro-elastic layer is correspondingly thicker. A large number of haversian canals containing blood vessels, best observed on transverse section, are found in compact bone tissue. Lamellæ of bone are plainly visible throughout the ground substance and are arranged in the following manner:

There is a set of lamellæ extending parallel to the external surface of the bone, and another set similarly arranged around the inner marrow or air cavity. There are the so-called fundamental lamellæ — known also as periosteal and marrow lamellæ, or outer and inner circumferential lamellæ.[2] Around the haversian canals are concentrically arranged lamellæ, forming systems of haversian lamellæ. There is a system of interstitial lamellæ wedged in between the haversian system of lamellæ. Scattered between the lamellæ are found the spaces known as lacunæ, containing bone cells. It is probable that all lamellæ are in more or less direct communication with each other by means of fine canals or canaliculi. The canaliculi of the haversian lamellæ of bone

are composed of fine white fibrous tissue fibrils imbedded in a ground substance in which they are arranged in layers superimposed in such a way that the fibers in the several layers cross at right angles, forming an angle of 45 degrees with a long axis of haversian canals.

In each lacuna there is found a nucleated bone cell which practically fills it, with its processes extended out into the canaliculi.

The haversian canals contain blood vessels, either an artery or vein or both. Between the vessels and the walls of the canals are perivascular spaces bounded by endothelial cells. Into these spaces the canaliculi of the haversian system empty. All lacunæ and canaliculi should be considered as filled by lymph plasma which circulates throughout the bones, bathing the bone cells and the processes.[3] In the fetal skeleton it is found that some bones are formed from a fibro-elastic membrane, such as those forming the roof and side of the skull. Others, such as the bones of the extremities, are formed from cartilage. Thus we find two kinds of ossification, intrafibrous and intramembranous and intracartilaginous.[4]

In the intrafibrous ossification no cartilaginous mould or stage precedes the appearance of the bone tissue. The membrane which occupies the place of the future bone is of the nature of connective tissue, and ultimately forms the periosteum. The outer portion is more fibrous than the internal, in which the cells or osteoblasts predominate. The whole tissue is richly supplied with blood vessels.

*Beginning of the Process*

At the onset of the process of bone formation a small network of bone spiculæ is first noticed, radiating from the point or center of ossification. A miscroscopic study shows it to consist of a network of fine, clear fibers with an intervening ground substance. These are called osteogenic fibers. They soon take on a dark granular appearance from the deposit of calcareous granules in the fibers and the intervening matrix. As they calcify they are found to inclose some of the granular corpuscles or osteoblasts. The latter form the corpuscles of the future bone, and the spaces in which they are inclosed are the lacunæ. As the osteogenic cells grow to the periphery they calcify and then give rise to fresh bone spiculæ.

The meshes of the network of bone thus formed contain blood vessels and delicate connective tissue crowded with osteoblasts. These bone spiculæ thicken by the accretion of layers formed by the osteoblasts, and the meshes become smaller. Subsequently separate layers of bone tissue are deposited in the periosteum and around the large vascular channels.[5]

In the intracartilaginous ossification we find the primary bone entirely cartilaginous, and in the long bones the process commences in the center (shaft ossification) and extends toward the extremities, which for

some time remains cartilaginous. Subsequently, a similar process commences in one or more places in these extremities (epiphyseal ossification), and gradually extend from them. Growth of long bones in length in the fowl takes place from the cartilaginous portion of the ends.

### *Ossification of Cartilage*

The first step in the ossification of cartilage is the enlargement of the cartilage cells, which arrange themselves in rows at a point termed the center of ossification. The matrix in which they are imbedded increases in quantity, so that the cells become further separated from each other. A deposit of calcareous material now takes place in this matrix, presenting a granular and opaque appearance. Here and there the matrix between two cells of the same row also become calcified, and the transverse bars of calcified substance stretch across from one calcareous column to the other. Thus there are longitudinal growths of cartilaginous cells inclosed in oblong cavities, the walls of which are formed of a calcified matrix which cut off all connection between other groups of cells, and thus primary areolar spaces are formed.

During the same time this process is going on in the center of the solid bar of cartilage of which the fetal bone consists, certain changes also are taking place on its surface. This surface is covered by a vascular membrane, the perichondrium, the inner surface of which is in contact with the cartilage, and on which are gathered the formative or genetic cells, called osteoblasts. These cells form a thin layer of bone tissue between the perichondrium and the cartilage. In this first stage of ossification there are two processes going on simultaneously: (1) In the center of the cartilage the formation of a number of oblong processes, and (2) on the surface of the cartilage the formation of a layer of true bone.

### *Second Stage of Bone Formation*

The second stage in the formation of bone consists of prolongation into the cartilage of processes of the osteogenic layer of the perichondrium, which has now become periosteum. The processes consist of blood vessels and cells, osteoblasts or bone formers and osteoclasts or bone destroyers. The latter are similar to the giant cells found in the marrow. They excavate passages through the newly formed bony layers and grow through into the calcified matrix.

Wherever these processes come in contact with the calcified walls or the primary areolæ they absorb them, and thus cause assimilation of the original cavity and the formation of large spaces known as the medullary spaces. These spaces become filled with embryonic marrow, consisting of vessels carrying osteoblasts on their walls, and are derived in the manner described above from the osteogenic layer of the priosteum.

The walls of the medullary spaces are of considerable thickness at this time, but they become thickened by the deposit of layers of new bone in their interior in the following manner:

Some of the osteoblasts arrange themselves as an epithelioid layer on the surface of the wall of the canal. This forms a bony stratum and thus the space becomes gradually covered with a layer of true osseous substance. By the repetition of this process the original cavity becomes very much reduced in size, and at last remains a small circular hole, containing blood vessels and a few osteoblasts. This small cavity constitutes the haversian canal of the perfectly ossified bone. These canals are essential in the regeneration of bone.

Other changes may be observed at the centers of ossification. A similar process has been set up elsewhere and has been gradually proceeding toward the end of the shaft, so that in the ossifying bone all the changes described above may be seen in different stages, from the true bone in the center of the shaft to the hyaline cartilage at the extremity.

## II. THE REPARATIVE PROCESSES OF BONE

### *Fracture of Bones*

A fracture may be defined as a sudden dissolution of continuity in a bone. The causes of these in a fowl are:

First, injury or trauma, as may be caused by a blow from a stone or stick or by being stepped upon by a large animal such as a horse or cow, or by a gunshot wound.

Second, muscular action. The effect of this can be seen when it is known that bones are most resistant first to traction, next to pressure, still less resistant to flexion or bending, and least of all to torsion.

External violence may be direct or indirect. In fracture from direct violence the bone is broken at or near the spot where the violence is applied. As a rule, the soft structures surrounding the fracture are more or less injured, and more serious results may follow than in fractures by indirect violence. In fractures caused by this direct violence the bone may be comminuted or fissured and perhaps driven into vital organs, as the liver or lungs, if the fracture be near those regions, or into the brain if it be near the cranial region.

In indirect violence the fracture occurs at a distance from the spot where the violence is applied. The bone usually breaks at its weakest point. The fracture may be rendered compound from the fragments, which often are much displaced and are sharp and irregular, being driven through the soft parts.

External violence is the most common cause of fracture in the fowl. The most common bones that are fractured by this cause are those of the legs, and, next, those of the wings.

Pathologic fractures are those from disease. Disease may also become predisposing causes of fractures from slight violence.

### *Classification of Fractures*

Fractures may be classified as follows:

First. Simple fractures. These are breaks in the continuity of the bone, and the skin is not broken.

Second. Compound or open or complicated fractures. These are fractures where the break is accompanied by a break through the skin and soft parts, extending to the seat of the fracture.

A fracture, whether simple or compound, may be spoken of as:

First, according to their extent, as (*a*) complete, when the bone is broken across; (*b*) incomplete or greenstick, when partly broken or partly bent (often seen in quite young chicks); (*c*) comminuted, when broken into several pieces; and (*d*) multiple, when two or more distinct fractures occur in the same bone or in different bones.

Second, according to the condition of the fragments, as (*a*) impacted, when one fragment is driven into another; (*b*) fissured, when extending through the bone without displacement, or (*c*) infraction depressed, when one fragment is pressed in below the surface, as in some fractures of the cranium; (*d*) punctured, when there is a small perforation with driving inwards of the fragments; and (*e*) splintered, when only a fragment of a bone is chipped off.

Third, according to the line of fracture, as (*a*) transverse, (*b*) oblique, (*c*) spiral, (*d*) longitudinal, (*e*) Y- or T-shaped, and (*f*) stellate.[6] All six of these fractures are recognized.

A fracture is spoken of as "complicated" when associated with other injuries, such as dislocation of the same bone, rupture of the principal artery of the limb, injury of an adjoining viscus, as the brain or liver, or implication of the joints.

Displacements of the fragments often occur. The cause of displacements may be as follows: The violence producing the fracture; careless handling of the injured bird; injudicious movements on the part of the bird; the weight of the lower fragments; and muscular spasms acting on the upper fragments. The amount of these displacements will depend in part on the direction of the line of fracture, and, in part, whether or not the periosteum is torn. The displacement is spoken of as angular, lateral, longitudinal, or rotary.

### *Symptoms of Fracture*

The general signs of fracture in the fowl are unnatural attitude of the wing or leg, inability to use either, alteration in the shape of the part,

and a swelling, shortening, or crepitus. In handling the part the feeling of the sense of crepitus is a diagnostic symptom.

If the fractured ends glide past each other, the contraction of the muscles may cause a shortening of the limb. The muscles of the fowl are loosely connected by fascia and displacement of the fractured ends of the bone is common. Pain usually accompanies a fracture in the bird.

So-called fracture fever may occur in the case of a break of the femur. This elevation of temperature may last for a day or two. It is supposed to be due, at least in part, to the absorption of tissue products.

## *Process of Repair*

The union of fractures by callus is similar to that which takes place in the healing of the wound of the soft parts by first intention. Blood is at first extravicated between and around the fragment until the ruptured or torn vessels are closed by clot. Within twenty-four hours after the injury there begins a simple inflammation from the torn vessels of the bone, the periosteum and the surrounding soft parts. This process includes an emigration of leucocytes and an exudation of fluid.

Then commences repair. The cells of the osteogenic layer of the periosteum begin to proliferate, and to a less extent the same is true of the bone corpuscles and surrounding endothelial and connective tissue cells. These cells gradually infiltrate, remove the clot, and collect to form the temporary callus. From the second day onward, cells (phagocytes) are seen containing remains of leucocytes, red blood corpuscles, and tissue fragments. In a simple normal fracture there is no emigration of leucocytes or pathologic exudation after six days.

The mass of soft, red, gelatinous granulation tissue is composed of tissue cells, derived from the periosteum, bone, and connective tissue, which are similar to the fibroblasts in a wound, with the addition that cells, especially those from the periosteum, have osteogenic properties, are osteoblasts.[7] Between these cells newly formed capillaries grow in from the vessels in the haversian canals, periosteum, and neighboring connective tissue. The formation of new bone in the callus is like the development of bone in membrane. There is, in addition, a variable amount of a firm, gelatinous intercellular substance, which when in considerable amounts distinctly separates the cells, and gives a bluish appearance to the naked eye, and is called cartilage. It appears that when the fractured ends of the bones are kept at rest and in perfect apposition, and with a normal rate of callus formation, the process is one entirely of formation of bone in membrane, without any preformed cartilage; but, on the other hand, if the bones are not in proper apposition movement of

the ends and a delayed formation of callus, islands or masses of cartilage may appear.[8]

The osteoblasts from the periosteum give rise to the ensheathing callus and to the definitive callus, especially in the case of long bones. The callus is found replacing the periosteum, and extending for some distance around the bone both above and below the line of fracture, forming a spindle-shaped tumor, by which the ends of the fragments are surrounded. It also replaces the structures within the canal by similar substance forming the provisional plug or internal or endosteal callus; and between the ends of the fragments the permanent intermediate or definitive callus.

The ensheathing callus and the internal callus are gradually organized into fibrous tissue, becoming harder and firmer. The outermost layers of the fibrous tissue into which the ensheathing callus is thus converted form a new periosteum. Ossification of the ensheathing callus is given by Spencer and Gask as beginning on the twelfth to the fifteenth day in the human,[9] but in fowls it is much earlier. This process usually begins in the angle between the periosteum and the bone, and extends along the surface of the bone, and also along the surface of the ensheathing callus beneath a new periosteum, till the upper and lower layers of the ossifying callus meet opposite the line of fracture.

Ossification of the internal callus goes on in a similar way, but begins a little later. The permanent callus, as soon as the ends of the bone are thus fixed by the ensheathing and internal callus, also undergoes ossification. The ossified callus is at first very vascular and porous, and can easily be stripped off the old bone, but later it becomes hard and dense, through formation of new bone around its blood spaces, and is then intimately connected with the old bone beneath it. Finally the ensheathing callus and internal callus, having completed their function, are gradually absorbed, and if the fragments have been held in good apposition no sign of the fracture may ultimately remain. Spencer and Gask give the time for such processes as being complete in the human at six or eight weeks, and that many months elapse before repair can be spoken of as complete.[5] In the fowl these processes are much more rapid.

The process of absorption of the temporary callus consists in the removal of the lime salts, leaving fibrous tissue, which in turn undergoes absorption, so that muscles, tendons, and nerves involved in the callus become freed and regain their function.

### *The Healing of Improperly Set Fractures*

Where the bones are not in exact apposition a modeling process occurs which may transform much of the internal structure of the bone.

The course of the septa, whether in persisting ensheathing callus or in the bone itself, takes a changed direction in accordance with the altered transmission of weight through the bone and the different angle at which the muscles pull.

Where the ends of the fragments overlap, the ensheathing callus fills up the angles; and while the open end of the medullary canal in each fragment in thus closed, its continuity through the bone is restored by the absorption of the intervening walls of the contiguous and overlapping fragments. Where the fragments are not in contact, the intervening space becomes filled with the ensheathing callus, which is then sometimes called interposed callus. Where the fracture is comminuted, the splintered fragments become glued, as it were, together, and to the main fragments by the ensheathing callus formed from the vascular tissue in which they become surrounded. When the fragments are in good apposition and are kept relatively at rest little ensheathing callus is found; but where there is much displacement, or where rest is impossible, as in a fracture of a rib, or difficult to obtain, as in a fractured clavicle, a considerable amount is produced.

The series of studies here presented are of two kinds: First, a study of the reparative processes; second, a study of the means of control of the fracture and care of the bird.

Figure 1 illustrates the study of a series of fractures that have been repaired for a considerable length of time. *A* shows a repaired ulna which has sustained an angular break, with a sliver of bone split off of the upper side and extending nearly to the proximal end of the bone. *1* shows the repair and a porous provisional callus. At *2* is shown that the reparative bone material has been lavishly used. Letter *C*, Nos. *6* and *7*, show the same. Letter *B* shows a tibia and fibula of a hen which has sustained a fracture at right angles to the shaft of the bone—(*3* is the fibula; *4* the tibia; *5* the repaired fracture). That this fracture has been repaired a long time is indicated by the fact that practically all of the provisional callus has been removed by absorption. Letter *D* shows the bone at a different angle, and shows at *8* the fibula, at *9* the tibia, and *10* the repaired fracture. This bone was improperly cared for, and hence a crooked leg was the result.

A series of studies were made of the nature and rapidity of repair of fractured bones of a domestic fowl. The birds were chloroformed and the bones fractured and set while the birds were under the anesthesia. The metatarsus and ulna were selected. The material used to hold the bones in place were cotton, one-inch cotton cloth bandage, wooden splints, and glue. At the end of each experiment the bird was again chloroformed and the bone removed. After a physical examination of the bone it was sectioned longitudinally, photographed, and the lesion

of one-half cut out and placed in 10 per cent hydrochloric acid solution for forty-eight hours for decalcification, and then passed through three changes of absolute alcohol, and then through equal parts of alcohol and ether, then imbedded in histoloid and sectioned. The sections were stained in hematoxylon and eosin and clarified in oil of cedar and mounted in natural balsam for study. Figure 2, letter *A,* shows a sectioned surface of a metatarsus of a Single-Combed Rhode Island Red cockerel eight days after the fracture. There was a mottled reddish white zone in the region of the fracture, indicating that immediately following the fracture there was an extravasation of blood which had collected around and between the fragments and between the ends of the compact portion of the bone, and had also invaded, to a certain extent, the marrow cavity. The fluid at this time gave some evidence of advanced organization and was rather callus-like, but allowing the fractured ends of the bone to separate when traction was applied.

There was present the initial hyperemia of repair. This hyperemia was most marked in the periosteum. Leucocytes, whose function it is to digest and remove the detritus resulting from the injury, had invaded the parts. Proliferated changes had taken place in the connective tissue, and in fact this was observed in cases of only forty-eight hours standing. The most active cellular multiplication was in connection with the fibrous structure of the periosteum. This forms the germinative or reparative tissue from which arises the osteoblasts. The nature of the new formed structure was that of connective tissue, and in Figure 4 may be seen the commencement of this organization into trabecular-like arrangement forming the periosteal callus and the provisional plug. It can be seen that this has been poured out and formed from the periosteum. This field shows many fibroblasts and is packed with osteoblasts and osteoclasts, and in still other fields of the trabeculæ a homogeneous matrix with formative bone cells in their lacunæ. The repair is apparently one of intramembranous bone formation, with islands of new formed bone at thé end of the fifth day.

In Figure 2, Letter *B,* is seen a sectioned surface of a fractured metatarsus of thirteen days standing. This bone is from a one-year-old Single-Comb White Leghorn hen, who was of low vitality and the reparative processes were more tardy than in section, letter *C*, shown in the same cut. After the metatarsus was removed it could with considerable force be made to spring, which was not the case in *C*, where the same amount of force was used. Both birds showed the reparative processes far enough advanced to have the appliance or cast removed with safety.

From these two studies it is rather indicative that repair of the bone of the domestic fowl is quite rapid and that twelve days is ample time to allow the bandage or cast to remain in place.

Figure 5 shows a photomicrograph of a section of the fractured portion of the bone shown in Figure 2, letter *C*. Figure 5 at 2 shows the periosteal or ensheathing callus, at 3 the internal or endosteal callus, and 4 the intermediate or definitive callus. A comparison of the calluses in Figures 4 and 5 show at a glance that the formation of bone in Figure 4 is just commencing to near completion in some of the trabeculæ, while in Figure 5 the process is nearly completed. Newly formed bone cells are plainly visible in the photomicrograph.

Figure 3 shows a series of studies at different ages. No. 1 shows the ulna of a Single-Comb Rhode Island Red cockerel nine months old. This fracture was of eight days standing. The left-hand view shows the provisional callus which appeared irregular in outline but smooth surface and whitish and pink mottled, indicative of a normal reparative process. The right-hand view shows the same in inner section. The process showed in the eight-day specimen marked advancement of complete normal bone tissue over the five-day specimen, but the firmness of the fractured end was not such that the bandage could have been removed safely. Number 2, in the same one-year-old Single-Comb White Leghorn hen, shows the process at the eighth day in a similar stage to the previous case. No. 3 of the same cut shows a case at fifteen days standing.

Numbers 4 and 5 show two cases of the tibia of a Buff Plymouth Rock hen in which the muscles of the tibial region had pulled the fractured ends past each other; thus a vicious repair was the result. It will be noted that the ensheathing callus has filled in the angles so that the fractured portion presents an irregular roundish appearance.

The ninth and tenth cases were Buff Orpington and Single-Comb White Leghorn respectively. The ulna was fractured and allowed to proceed ten days in its reparative process.

## III. THE TREATMENT OF FRACTURES AND CARE OF THE BIRD

Following the definite diagnosis of fracture of a bone in the fowl, the next step is to detremine if any wound has been made which extends through the flesh and skin.

In simple or so-called subcutaneous fracture the fragments of bone should be placed in perfect apposition and the normal shape of the bone restored. The loose arrangement of the muscles makes this an easy task.

The next step is to apply apparatus holding the parts firmly in place until firm union has taken place. Spasmodic contraction of muscles is not likely to be encountered except in the thigh, arm, or breast muscles. In applying the apparatus, normal functions, as circulation and nerves, must be safeguarded. After the setting is complete, the bird must be provided with a clean coop and grassy run where other birds

will not interfere. Good food and water and an occasional examination to determine if all is well with the bone undergoing repair is also needed.

*Setting of Fracture*

If the fracture is on a feathered part, the feathers in the region to be manipulated should be removed. Next, apply a thin layer of cotton, holding carefully the fractured part in the proper position, then apply about three thin, narrow wood splints (somewhat shorter than the fractured bone) in such a manner as not to later chafe the skin and make a sore, and, then apply one-inch cotton bandage, applying at the same time glue or laundry starch. In a few hours the glue or starch (preferably glue) will be dry and the parts held firmly in position. Plaster of Paris may be used in the place of glue, but the cast will be found to be rather heavy for a small animal like the fowl.

At the end of twelve or thirteen days carefully remove the appliance, dissolving the glue or starch in warm water. Confine the bird for a few more days longer in a separate compartment.

In feeding for the first two or three days it is well to feed mash or bread soaked in milk, and then gradually feed corn, wheat, and oats, as for other fowls, and give milk or water to drink. If there are no internal injuries or other complications the birds will not greatly suffer.

It is found that in fractures near the joint the new bone thrown out in reparative processes may result in a stiff joint. Where the joint is stiff it is found that the tendons are more or less adherent to each other and to the fractured part, and at times they may be atrophied. Muscles of the bird which are not brought daily into use soon undergo atrophy.

One of the unfavorable outcomes of a fracture is a false joint or pseudoarthrosis in which is had an ununited fracture of some standing in which the ends of the fragments are rounded off and eburnated, or covered with a layer of fibro-cartilage, and inclosed in a strong fibrous capsule formed by the condensation of the surrounding soft tissue. If the fracture is near the articular ends of bones where a rotary as well as angular movements take place, the false joint may resemble a ball and socket joint, or it may resemble a hinge joint. If the fracture is through the shaft of a bone, and angular movements alone take place, the false joint is likely to resemble a hinge joint. Some of the more common causes for these false joints are: The fragments not having been kept thoroughly at rest; the fragments not having been kept in perfect apposition, as a sequala of muscular contraction; the loss of large pieces of bone, as in compound fractures; the intervention of a piece of tendon, muscle, periosteum, or bullet, as in gunshot wounds and fractures; and the effusion of synovial fluid in the case of fracture into joints.

False joints may be the result of necrosis of the ends of fragments, the poor supply of blood to the fragments, defective nerve influence, as may occur in injury of the spinal cord, malignant growths, and osteomalacia.

Compound fractures or open fractures are those where there is a wound through the skin and other soft structures extending into the fracture. This form may be produced in different ways. The violence causing the break of the bone may be sufficient to tear open the soft tissue, or a fragment may be forced through the parts, or the bird in its movements after the accident may force one of the fragments through the soft structure and the skin. Ulceration may take place later in a bruised or injured part directly over the fracture. This necrosis is preceded by congestion, then inflammation and molecular death.

A wound in compound fracture may be large or may be nothing more than a small puncture. In the case of gunshot wound, and where large animals have stepped on the limb, the bone may be badly crushed. If the wound be a small puncture, with no infection, and the bird is greatly resistant to infection, the repair may take place as in simple fracture. When the wound is large and infection has taken place (which infection may be septic), and there has been laceration of the soft part (or comminution of the bone), union is affected by granulation from the ends of the fragments and periosteum, the process being similar to union of soft parts by second intention or by granulation. The loose parts and fragments are cast off by sloughing. If the fragment is in connection with the periosteum and receives nourishment, it may be retained. If the portion of the bone be denuded of periosteum, that part usually undergoes necrosis and is cast off. If it is not properly cast off, and is surrounded by new bone, it may remain a source of irritation. Some of the dangers of these compound fractures are necrosis of bone, gangrene of the limb, and septicemia.

In applying the bandage to an open fracture it is best to place a small piece of cork or wood over the wound and, after applying the dressing, cut down through the dressing and remove the cork. In this way a drainage window is established and through this the wound may be treated daily with an antiseptic wash.

Vicious union is a condition which results where the leg has been improperly set or the bandage removed too early and the weight of the bird causing the bone to unite at an angle. In this case deformity of the limb is the result.

A series of cases were studied from a practical treatment standpoint. Figure 6 is a röntgengraph showing a normal femur. Figure 7 shows a röntgengraph of a properly set fracture. Figure 8 is a röntgengraph which shows an improperly set tibia. This is of three

days standing. This fracture, if allowed to remain in this condition, would have made a vicious union and a deformed limb, which in a show bird is a serious defect.

Figure 9 shows a fracture six days standing and Figure 10 is a röntgengraph of the same fracture at nine days standing. It will be noticed that the callus is becoming more dense, due to the increased molecular density brought about by the reparative process. Figure 11 shows the same fracture twelve days standing.

Figure 12 shows a plaster of Paris cast which was used on case No. 15. These casts are rather heavy for birds.

Figure 13 shows a fracture with adjustment and appliance in place. This is a fracture of a tibia in a three-pound Single-Comb Rhode Island Red pullet. The appliance consisted of cotton, wooden splints, one-inch cotton bandage, and glue. Glue has proven the most satisfactory in the experience of this laboratory.

Figure 14 is the last of the series of twenty-one birds studied. *A* shows a normal shank and *B* a vicious union, with deformity. This is similar to numbers 3 and 4 in Figure 3. It was a Buff Plymouth Rock cock, which was rendered blemished for show purposes due to improper care of the fracture.

In one case where the bones of the wing were not in perfect apposition, and not securely held, the bird was handled often and the ends of the bone moved frequently, there was found a few islands of cartilage. This was not observed where the broken ends of bone were firmly held in proper position.

## SUMMARY

A series of twenty-one cases of fractures were studied in the domestic fowl. It was found that at the end of the fifth day islands of bone tissue had begun to form.

The repair of fractures in the domestic fowl is intramembranous.

The periosteal, endosteal, and intermediary calluses show bone formation in trabecular-like arrangement.

By the end of the thirteenth day the major portion of the bone tissue had formed and was found completed before the twentieth day.

The appliance used to hold the broken bones in apposition in the domestic fowl may be removed with safety by the end of the twelfth or thirteenth day.

The structure of compact bone in the domestic fowl is similar to that of mammalia.

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# DESCRIPTIONS OF THE ILLUSTRATIONS

FIG. No. 1—*A*, a broken ulna. *1* shows the diagonal fracture, with repair complete. Note the porous bony mass. *2*, a splintered piece of bone which has been united to the main bone in the reparative processes.

*B*, a broken tibia which has been repaired. *3*, the fibula. *4*, the tibia, *5*, the point of fracture.

*C*, a side view of *A* (smaller magnification).

*D*, *8*, the fibula. *9*, the tibia. *10*, the point of fracture. The provisional callus has been largely absorbed.

FIG. No. 2—*A*, a fracture of the metatarsus five days standing. Properly set. From a three-year-old S. C. Rhode Island Red hen. *1*, the fracture. At this stage the exudate had not fully organized.

*B*, fracture of the metatarsus thirteen days standing. From a one-year-old S. C. White Leghorn hen. Hen rather low in vitality. *1*, the provisional callus. *2*, the provisional plug. *3*, the normal metatarsal wall at break. The bone shows a slight spring upon the application of considerable force.

*C*, fracture of metatarsus thirteen days standing. From an eight-months-old S. C. Rhode Island Red cockerel. *1*, the provisional callus at the point of fracture. *2*, the provisional plug. *3*, the normal metatarsal wall at point of the break. There was no spring when force was applied to this bone.

FIG. No. 3—*A*, photograph showing the outside surface of fractured bones.

*B*, photograph showing the inside surface of fractured bones. *1*, fracture eight days standing. *2*, fracture eight days standing. *3*, fracture fifteen days standing. *4* and *5*, fracture twenty-one days standing. The latter two and first are vicious union, the second and third are properly set.

FIG. No. 4—A photomicrograph of a section of the wall of the metatarsus of a cock. Fracture five days standing. *1*, splintered fractured end. *2*, the provisional callus. *3*, the provisional plug. *4*, the bone cells of the normal bone. *5*, the endosteum. *6*, the haversian canals.

FIG. No. 5—An oblique fracture of thirteen days standing. *1*, the fractured ends which have been placed in perfect apposition in the process of setting. *2*, the provisional callus. *3*, the provisional plug. *4*, intermediate callus. *5*, the periosteum, one of the sources of the new bone cells.

FIG. No. 6—A röntgengraph of a normal tibia.

FIG. No. 7—A röntgengraph of a fracture. Properly set.

FIG. No. 8—A röntgengraph of a fracture of three days standing. Not properly set. Note the appearance of the provisional callus filling in the angles around the fracture.

FIG. No. 9—A röntgengraph of a fracture of six days standing (same case as in No. 8). Note provisional callus.

FIG. No. 10—A röntgengraph of a fracture of nine days standing (same case as in No. 8). Note the increased density of the provisional callus. The density of the shadow depends upon the molecular density of the tissues. The molecular density of the callus becomes greater as reparative processes advance.

FIG. No. 11—A röntgengraph of the same case at twelve days standing.

FIG. No. 12—A plaster of Paris cast from a hen with a broken tibia. Slightly enlarged. Weight 55 grams.

FIG. No. 13—A four-months-old S. C. Rhode Island Red pullet with a broken tibia. Properly set, using splints (No. 1), cotton (No. 2), one-inch cotton bandage (No. 3), and glue.

FIG. No. 14—*A*, a normal metatarsus of a cock.

*B*, a repaired fracture showing an improperly set bone and a vicious union.


·FIGURE No. 1

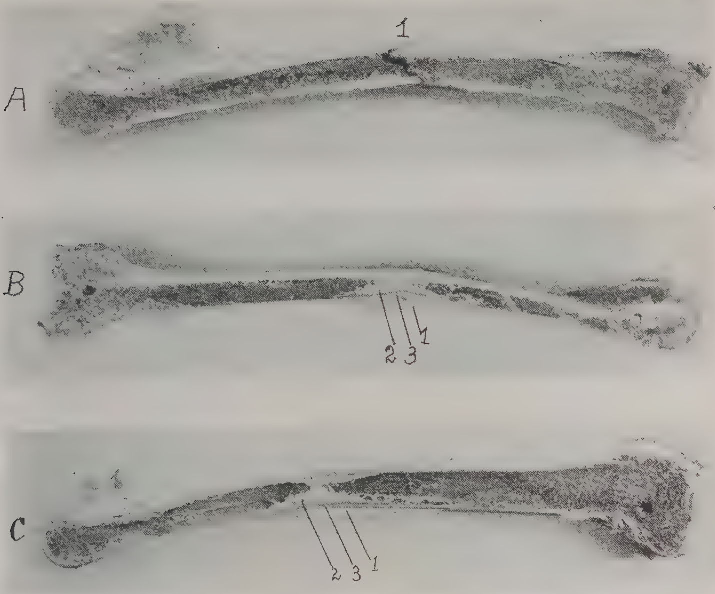


Figure No. 2

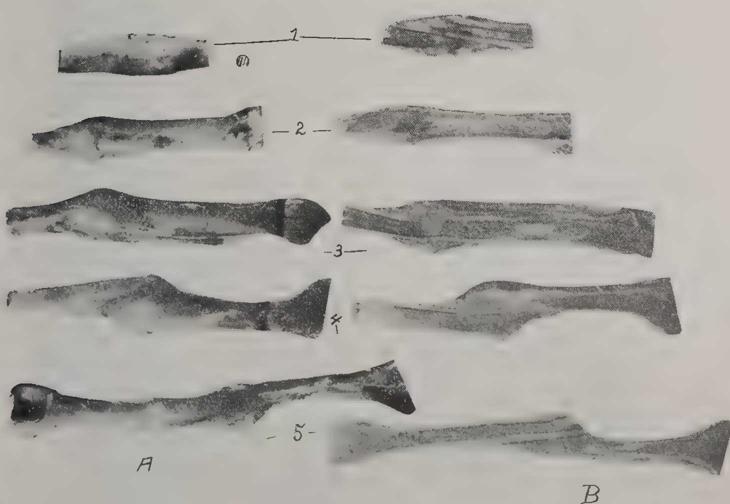


Figure No. 3

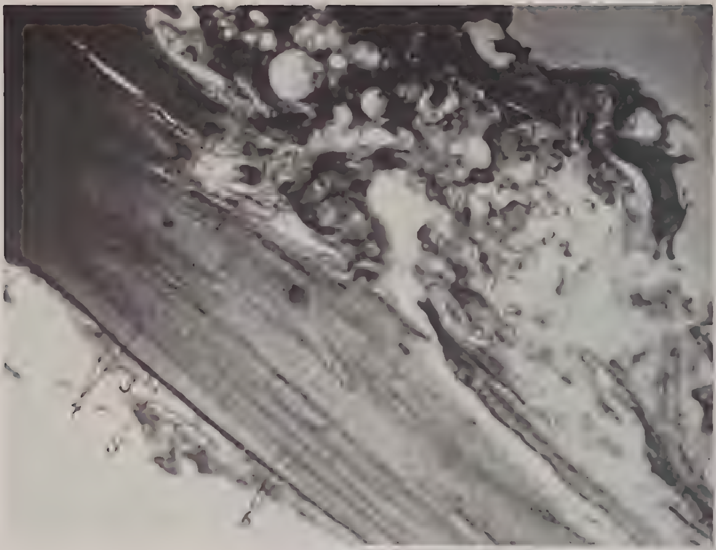

FIGURE No. 4

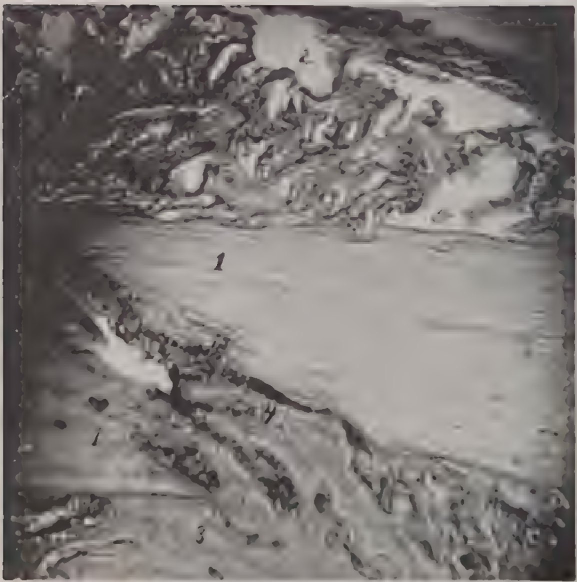

FIGURE No. 5


Figure No. 6

Figure No. 7


Figure No. 8


FIGURE NO. 9


Figure No. 10


Figure No. 11

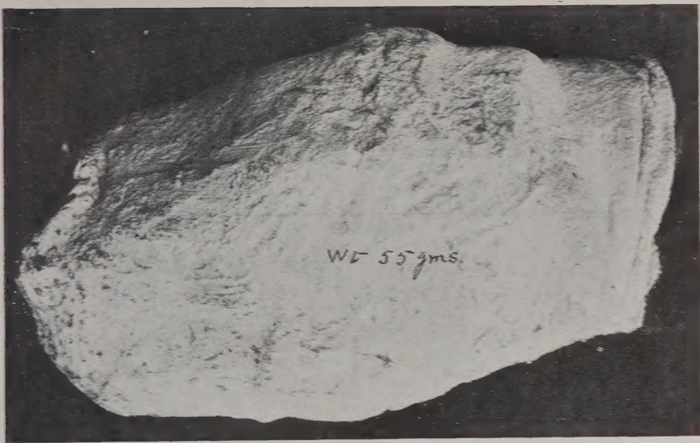


FIGURE No. 12


FIGURE No. 13


Figure No. 14